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EVALUATION OF GEOTHERMAL POTENTIAL OF RANGE BRAVO 17 AND THE SH--ETC(U)

MAR 80 J A WHELAN, C R RODGERS, J BROWN

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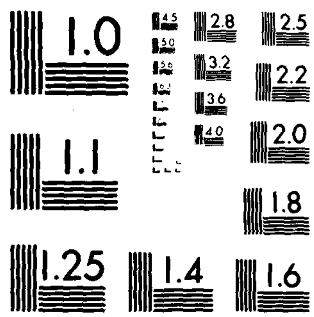

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NWC TP 6142

Evaluation of Geothermal Potential of Range Bravo 17 and the Shoal Site, Naval Air Station, Fallon

by

J. A. Whelan
C. R. Rodgers
J. Bown
Jack Neffew
Public Works Department

MARCH 1980

NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

The Naval Weapons Center has been tasked with evaluating the geothermal potential of naval installations throughout the world. The evaluation of the Shoal Site and Range Bravo 17 was conducted by the Naval Weapons Center during the period October 1978 through September 1979, under sponsorship of the Naval Civil Engineering Laboratory, Project No. Z0840-SL.

This report has been reviewed for technical accuracy by Dr. Carl F. Austin, Head, Utilization Division, Public Works Department.

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Released for publication by
R. M. HILLYER
Technical Director

NWC Technical Publication 6142

Published by . . . . Public Works Department
Collation . . . . Cover, 18 leaves
First printing . . . . 170 unnumbered copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14 NWC-TP-6142
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): 6 EVALUATION OF GEOTHERMAL POTENTIAL OF RANGE BRAVO 17 AND THE SHOAL SITE, NAVAL AIR STATION, FALLON.
5. TYPE OF REPORT & PERIOD COVERED: 9 Final Report, Oct[redacted]78-Sep[redacted]79,
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): 10 J. A. Whelan, J. Bown, C. R. Rodgers, Jack Neffew
8. CONTRACT OR GRANT NUMBER(s): 17 Z0840SL
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Weapons Center, China Lake, California 93555
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Naval Civil Engineering Laboratory Project No. 16 Z0840 SL
11. CONTROLLING OFFICE NAME AND ADDRESS: 12 39
12. REPORT DATE: 11 Mar[redacted]80
13. NUMBER OF PAGES: 34
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release, distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
    - Geochemistry
    - Geology
    - Geothermal
    - Hydrology
    - Seismic refraction
    - Thermal gradients and heat flow
20. ABSTRACT (Continue on reverse side if necessary and identify by block number): See back of form.

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S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(U) *Evaluation of Geothermal Potential of Range Bravo 17 and the Shoal Site, Naval Air Station, Fallon* (U), by J. A. Whelan, C. R. Rodgers, J. Bown, and Jack Neffew. China Lake, Calif., Naval Weapons Center, March 1980. 34 pp. (NWC TP 6142, publication UNCLASSIFIED.)

~~(U)~~ As part of the task of evaluating the geothermal potential of naval installations throughout the world, Range Bravo 17 and the Shoal Site, both located at the Naval Air Station, Fallon, Nev., were evaluated.

(U) An aeromagnetic survey was conducted; seismic refraction studies and extensive hydrologic studies were made; thermal gradient and heat flow data were taken; and water chemistry and mercury geochemistry analyses were made.

(U) The results of the study show that the geothermal potential of the Shoal area and Range Bravo 17 is low. It was concluded that further exploration of these sites is not warranted at this time.

A

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INTRODUCTION

It is important for the Navy to know the geothermal potential of its lands (1) to prevent or minimize encroachment, and (2) if the resources warrant, to develop energy self-sufficiency. Consequently, the Geothermal Utilization Division, Public Works Department, Naval Weapons Center (NWC), has been tasked with evaluating the geothermal potential of naval installations throughout the world.

As part of this task, the geothermal potential of Range Bravo 17 and the Shoal Site, both located at the Naval Air Station (NAS), Fallon, Nevada, was evaluated. The studies consisted of a literature review, a reconnaissance of the Shoal Site, and soil sampling for mercury over much of Range Bravo 17. Results of these studies are given in this report. Because of the large amount of data available in the literature (particularly in two reports on the Shoal Site[1,2]), the limited field work undertaken was considered adequate for an evaluation of the geothermal potential of the area. Additional work is not recommended.

GEOGRAPHY

The Naval Air Station, Fallon, and its associated ranges are located in a portion of Nevada with generally high geothermal potential. Stillwater-Soda Lake, Desert Peak, and Brady-Hazen, designated Known Geothermal Resource Areas (KGRA), respectively lie to the northwest and northeast of NAS Fallon, with the Stillwater-Soda Lake KGRA bordering the station to the north. Just southeast of NAS Fallon is the Salt Wells Basin KGRA. Lees Hot Springs is on the northeast corner of Range Bravo 19, and Oxygeothermal has drilled an observation hole there. The Electronic Warfare Range is in Dixie Valley. To the north are Dixie Hot Springs and the Dixie Valley KGRA. Sun Oil Company has drilled a commercial well in Dixie Valley. Range Bravo 17 is in Fairview Valley, a southerly extension of Dixie Valley. Range Bravo 20 has the Stillwater-Soda Lake KGRA to the south and the Brady-Hazen KGRA to the west.

Range Bravo 17, one of the areas evaluated in this study, lies to the south of U.S. Highway 50, about 40 miles southwest of Fallon and 75 miles east of Austin, Nevada. The Electronic Warfare Training Area lies just to the north of Highway 50 in the same area. Range Bravo 17 occupies a large portion of T16N, R33E, and about the western third of T16N, R34E (MDB and M).

The results of evaluating three additional areas are also presented in this report. These are two target areas–the northernmost consisting of S 1/2 Sec 22, S 1/2 Sec 32, SW 1/2

[1]Nevada Bureau of Mines. *Geological, Geophysical, and Hydrological Investigation of the Sand Springs Range, Fairview Valley and Fourmile, Churchill County, Nevada.* Reno, Nev., University of Nevada, 1962. 128 pp. (Publication UNCLASSIFIED.)

[2]———. *Project 33.2 Geological, Geophysical, Chemical, and Hydrological Investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Nevada.* Reno, Nev., University of Nevada, October 1963. 360 pp. (VUF-1001, publication UNCLASSIFIED.)

Sec 24, W 1/2 Sec 25, Sec 26, and Sec 27, T16N, R32E (MDB and M); and the southerly one consisting of Sec 10, Sec 11, W 1/2 Sec 12, NW 1/4 Sec 13, N 1/2 Sec 14, and N 1/2 Sec 15, T16N, R32E (MDB and M)–and the lands between these two. In this latter area, which has been designated the Shoal Site, a 12.4-kiloton atomic device was detonated at a depth of 1,205 feet on 26 October 1963. Access to the target areas and Shoal Site is by U.S. Highway 50, south on Nevada State Highway 31 for 6.1 miles, and east 4 miles into the Sand Springs Range. Locations are given in Figure 1, and an air-photo of Fairview Valley is given as Figure 2. (No drilling or excavating is allowed within 3,500 feet of ground zero.)

CLIMATE

The Sand Springs Range and Fairview Valley have a typical Great Basin arid climate with about 5 inches of rain in the valley and 12 inches at the highest elevation (footnote 1).

The mean annual temperature at Fallon, as reported in a 1961 annual climate summary, is 50.6°F. January is the coldest month and July the warmest. The mean January temperature is about 33°F and that for July about 76°F. Extremes for those months are -14°F and 105°F (see Appendix A).

GEOLOGY

Both before and after the atomic test of 1963, detailed geological, geophysical, and hydrologic studies of the Shoal Site area were made by the Nevada Bureau of Mines, the Nevada Mining Analytical Laboratory, and the Desert Research Institute, all of the University of Nevada. Copies of the two reports prepared under the test contract (footnotes 1 and 2) were obtained for the writers by Robert Clarke, Nevada Operations, Department of Energy. Geologic data from these reports were used extensively in the present study.

A good general summary of the geology of the Sand Springs Range and Fairview Valley is given in the Nevada Bureau of Mines' first Shoal report (footnote 1): the following description is quoted from that report.

"The Sand Springs Range is made up chiefly of a Cretaceous granite intrusive body bordered on both the north and south by Mesozoic (?) metamorphic rocks.... Locally both the granite body and metamorphic rocks are overlain by Tertiary and Quaternary volcanic rocks.... Numerous aplite-pegmatite dikes cut the granitic body; most of these dikes are concentrated in a zone extending south along the western crest of the Range and swinging southeast to the granite-metamorphic contact. Many andesite and rhyolite dikes intrude the granitic body, the metamorphic rocks, and the aplite-pegmatite dikes. Tertiary and Quaternary alluvial and eolian deposits occupy the valleys to the east and west of the Range.

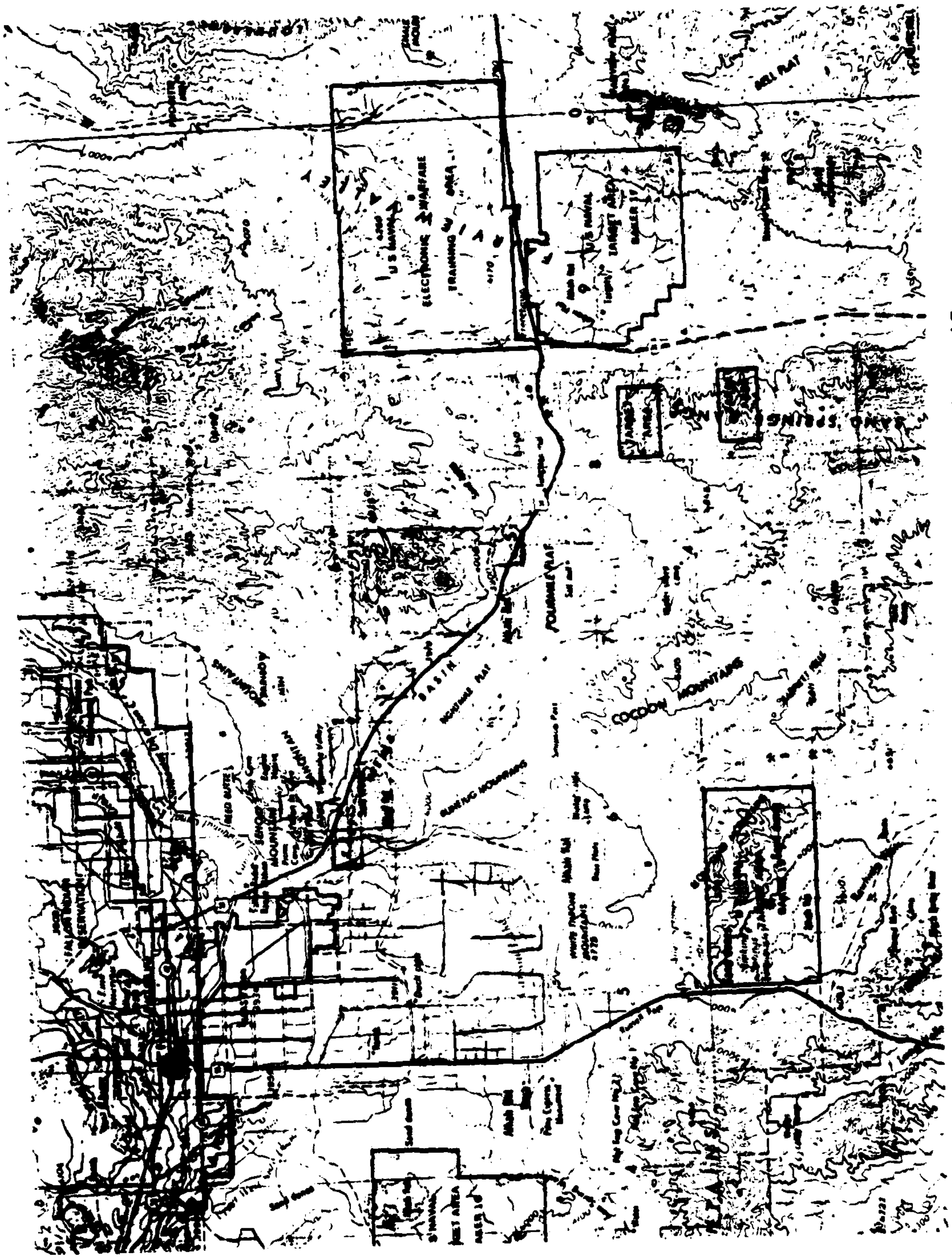


FIGURE 1. Location of Shoal Site and Range Bravo 17.

FIGURE 2. Aerial Photograph of Fairview Valley.

"Although the Range is a north-south trending fault block, north-south faults are rare, the Range having been uplifted along a series of northwest-and-northeast-trending high-angle faults, which form a sawtoothed pattern in plan. The down-dropped Fairview Valley block to the east contains over 5,000 feet of unconsolidated sediments; in contrast, the Fourmile Flat area to the west is a pediment, thinly veneered with alluvium near the Range, the alluvium thickening to about 1,300 feet immediately south of the salt flat.

"The structural pattern is remarkably consistent throughout much of the Range. A system of steeply-dipping faults and joints trending about N 60° W cuts the granitic body; most of the dikes are intruded along these structures. A second system of steeply-dipping faults and parallel, closely-spaced fracture cleavage, trending more or less N 30° E, cuts the granitic body and dikes. Other directions of faulting, jointing, and cleavage are common locally. A gently-north-dipping thrust cuts the metamorphic rocks just south of U.S. Highway 50; there is no evidence of thrusting elsewhere in the Range."

A geological map, adapted from the Nevada Bureau of Mines' second Shoal report (footnote 2) is given as Figure 3.

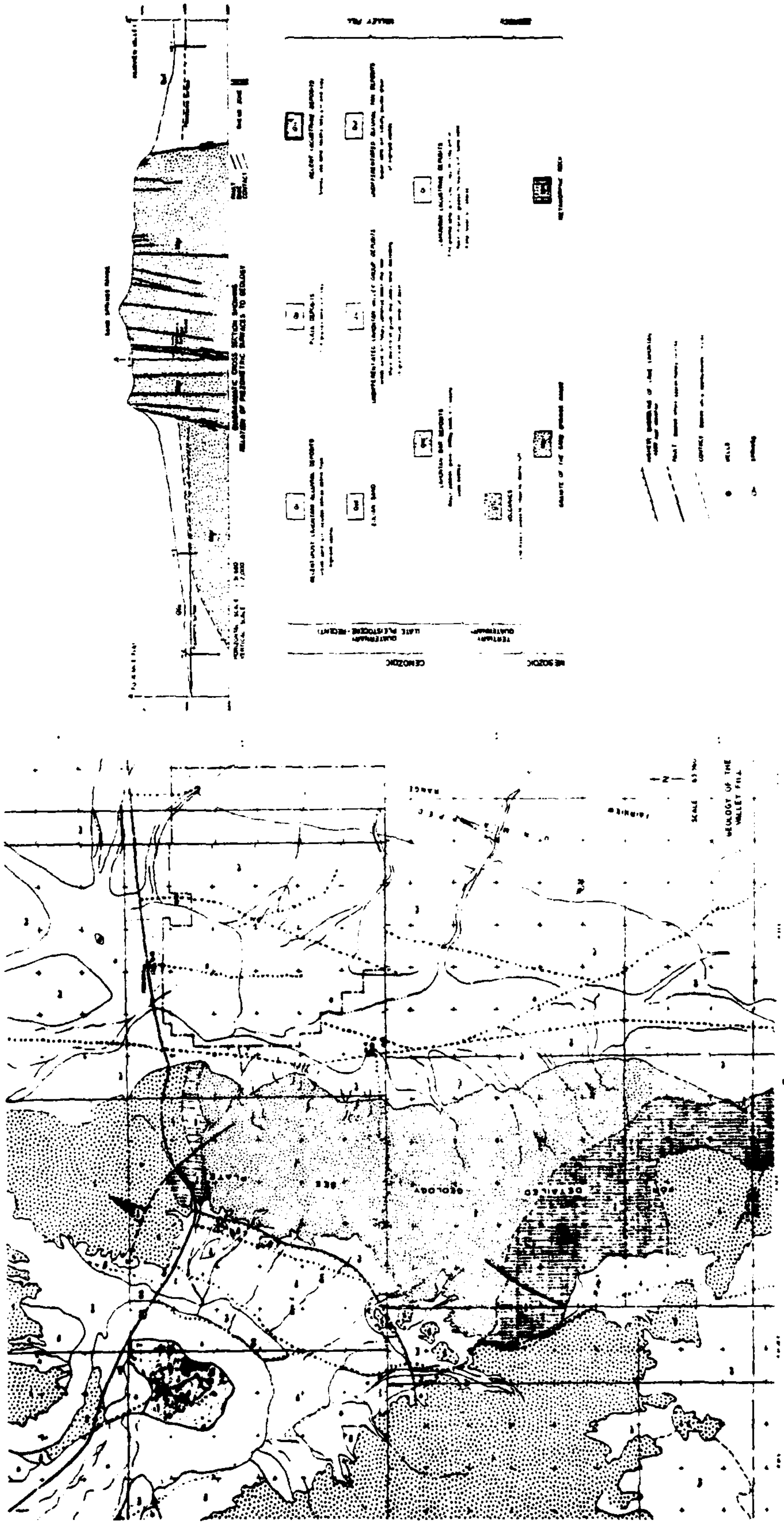
The undesignated target areas and Shoal Site are in the granitic portion of the range. The intrusive rock varies from porphyritic biotite granite to granodiorite, with the granodiorite predominating in the west central part of the range (footnote 1).

The granite is a porphyritic biotite granite with abundant, large orthoclase phenocrysts in a medium-to-coarse grained groundmass of quartz, orthoclase, plagioclase, varying amounts of small biotite flakes and/or books, and locally some hornblende.

The granodiorite appears to have both intrusive and gradational relationships with the granite. Potassium-argon age determination on biotite from the granite and granodiorite was 79.6 (±2.0) and 76.0(±2.0) million years respectively.

The aplite pegmatite dikes extend from less than 1 inch to more than 20 feet in width. Aplitic and pegmatitic material commonly occur in the same dike, usually with sharp contacts. In most cases, the aplite forms the borders of the dikes with pegmatite occurring as lenses, stringers, and continuous layers in the centers. Some dikes change to quartz veins along their strike. The aplite consists of 30 to 40% quartz, 20 to 50% plagioclase, 20 to 50% mirocline, and 1 to 15% muscovite. The pegmatite consists of mirocline, aplite, and biotite. The aplite dikes are cut by andesite and rhyolite dikes. A potassium-argon age determination—not considered reliable—gave an age of 30 (±6) million years for this rock.

Andesite dikes intrude the granite, metamorphic rocks, and aplite-pegmatite dikes. Two andesite dikes cut volcanic rocks. Andesite dikes occur throughout the range but are much more abundant in the northern half. These dikes are up to 50 feet wide; most trend N 50° W in the north half of the range and northeast in the south half, and they dip steeply. The basic dikes range from diabasic to diorite in composition but mostly are hornblende



Scale: 1 inch = approximately 4 miles.

FIGURE 3. Geologic Map of the Sand Springs Range and Fairview Valley. (Adapted from reference of footnote 2.)

andesites. Many of these dikes are porphyritic with phenocrysts of plagioclase and/or hornblende, while others are aphanitic. Some have porphyritic centers and aphanitic margins. The hornblende andesite contains 30 to 65% plagioclase (An_{30-55}), 15 to 60% hornblende, 2 to 5% magnetite, 1 to 5% biotite, 1 to 3% quartz, and less than 1% apatite. They are propylitically altered. Alteration minerals include chlorite, epidote, calcite, and quartz. In most cases, the andesite dikes are cut by the rhyolite dikes, but the reverse relationship has been observed (footnote 1).

Rhyolite dikes, up to 50 feet wide, intrude the granitic and metamorphic rock. They cut the aplite-pegmatite dikes and most of the andesite dikes. They trend N 50° W in the north half of the range, northeast in the south half, and have steep dips. Many are straight, long, and of even width, but the younger rhyolite dikes are curved, short, and variable in width. They range from rhyolite to dacite in composition. The three most common varieties are aphanitic rhyolite, quartz, porphyry with feldspar phenocrysts, and porphyry with both quartz and feldspar phenocrysts. The dikes are white to buff but commonly stain brown to reddish-brown on weathered surfaces. The aphanitic rhyolite consist of intergrown quartz and feldspar. The feldspar commonly is almost completely argillized and sericitized. The porphyritic rhyolite contains up to 30% phenocrysts of quartz, sanidine, and/or albite in a groundmass of the same minerals, plus 0.5% biotite. Some of the porphyritic rhyolite exhibits propylization, argillization, sericitization, and/or pyritization.

An intrusive breccia, consisting of inclusions, generally andesite and rarely granite, in a groundmass of pink and white aplite and porphyritic rhyolite, is exposed along the northeastern front of the Sand Springs Range. The inclusions range from gravel-sized, subrounded pieces to masses which have dimensions of hundreds of feet. Inclusions make up 20 to 50% of the rock.

Quaternary-Tertiary volcanic rocks unconformably overlie the metamorphic rocks at both ends of the Sands Springs Range and lie directly on the granite in several hills on Fourmile Flat to the west. An upper possibly Quaternary unit of basalt flowed west with various degrees of angular unconformity upon a possibly Tertiary unit consisting of an upper member of light-colored rhyolitic pryoclastics and a lower member of dark-colored andesite flows.

Of particular interest when considering geothermal potential are the rhyolites north of U.S. 50 and east of Sand Springs Pass. The description in the first Shoal report (footnote 1) is as follows:

"North of U.S. 50 and east of Sand Springs Pass several small erosional remnants of rhyolite vitrophyre are present near the top of the rhyolitic sequence. Probably all of these are at the same stratigraphic position and represent one large tabular, horizontal, shallow, glassy intrusive body or possibly an extrusive dome. The base and top of the vitrophyre are not present in any one exposure, but the body is probably less than 100 feet thick.

"The andesitic lower sequence rests with pronounced unconformity on the Mesozoic (?) metamorphic rocks in the northern end of the range. Locally, the rhyolitic sequence rests directly upon the metamorphics, indicating a profound local unconformity between the andesitic and rhyolitic sequences. In the southernmost part of the map area both the Quarternary (?) basalt and upper Tertiary (?) rhyolitic sequences are present, but the andesitic sequence is missing."

It would be highly desirable to obtain isotopic ages on the younger rhyolites.

Quaternary and Tertiary alluvial and eolian deposits occupy the valleys east and west of the Sand Springs Range. Fairview Valley, the site of Range Bravo 17, is characterized by playa deposits. On the basis of geophysical studies done for Project Shoal, the unconsolidated deposits are estimated to be 5,800 feet thick near the west margin of the valley a few miles south of U.S. Highway 50.

Folding is not a prominent feature in the Sand Springs Range. The metamorphic sequence at the south end of the range forms the western limb of a south plunging anticline, the eastern limb being the Fairview Range. Small-scale folding is uncommon in the Sand Springs Range except along the granitic-metamorphic rock contact where some drag folding of the metamorphics has taken place.

The Sand Springs Range is a north-south trending fault block uplifted along a series of high angle northeast and northwest trending faults. The first set trends about N 30° E and is accompanied by closely spaced, parallel-fracture cleavage. The N 50° W trending faults are accompanied by parallel joints. Most of the aplite-pegmatite, andesite, and rhyolite dikes are intruded along these faults and joints. Although many of these faults are narrow, some are wide and others are grouped together to form fault zones. Most contain gouge and brecciated wall rock. Iron staining, bleaching, and propylization is common in and along the faults. Primarily, the movement has been vertical, and has been from hundreds to thousands of feet, but it has been accompanied by some horizontal movement. These faults have been active from shortly after the intrusion of the granitic rocks until recent times.

A thrust fault cuts the metamorphic rocks at the north end of the range. It has a gently-north-dipping, undulating surface. The upper plate is garnetiferous, recrystallized limestone. The lower plate is metamorphic rocks. Offshoots of the granite body are exposed in contact with the thrust. Along the sole of the thrust the rock is bleached and stained. The direction of movement is not known.

A well-developed fracture cleavage is present throughout much of the granitic body and commonly parallels the northeast trending faults.

Deposits of tungsten occur in the metamorphic sequence at both the north and south ends of the range, in most cases in limestone at contact with the granite body. Scheelite and minor powellite occur, with garnet, cordierite, diopside, and calcite; and quartz veins containing scheelite cut the replacement bodies and surrounding rocks.

A system of east-west veins dipping steeply south, known as the Summit King System, occurs in a fault zone crossing the range just south of U.S. Highway 50. The veins cut metamorphic rocks. Tertiary volcanic rocks and andesite and rhyolite dikes occupy many of the individual fault strands. The veins are offset short distances by cross faults. At the surface, the veins have a braided pattern. The main southernmost veins dip 70 to 80 degrees south, and the subsidiary veins to the north dip 50 to 70 degrees south and intersect the main vein at shallow depths. The veins are 2 to 10 feet thick, contain fine-grained to vuggy quartz, angular fault breccia, and locally abundant calcite and pyrite. Ore minerals are native gold, cerargyrite (AgCl), and argentite (Ag_2S). The ratio of gold to silver is 1:40 in the upper level but decreases to 1:80 in the deeper workings. Underground workings reach depths of 450 feet. Several million dollars worth of silver and some gold have been produced from this vein system.

GEOPHYSICS

As noted previously, detailed studies of the Shoal site had been made (footnotes 1 and 2). Geophysical data from those studies were used extensively for this evaluation.

GRAVITY

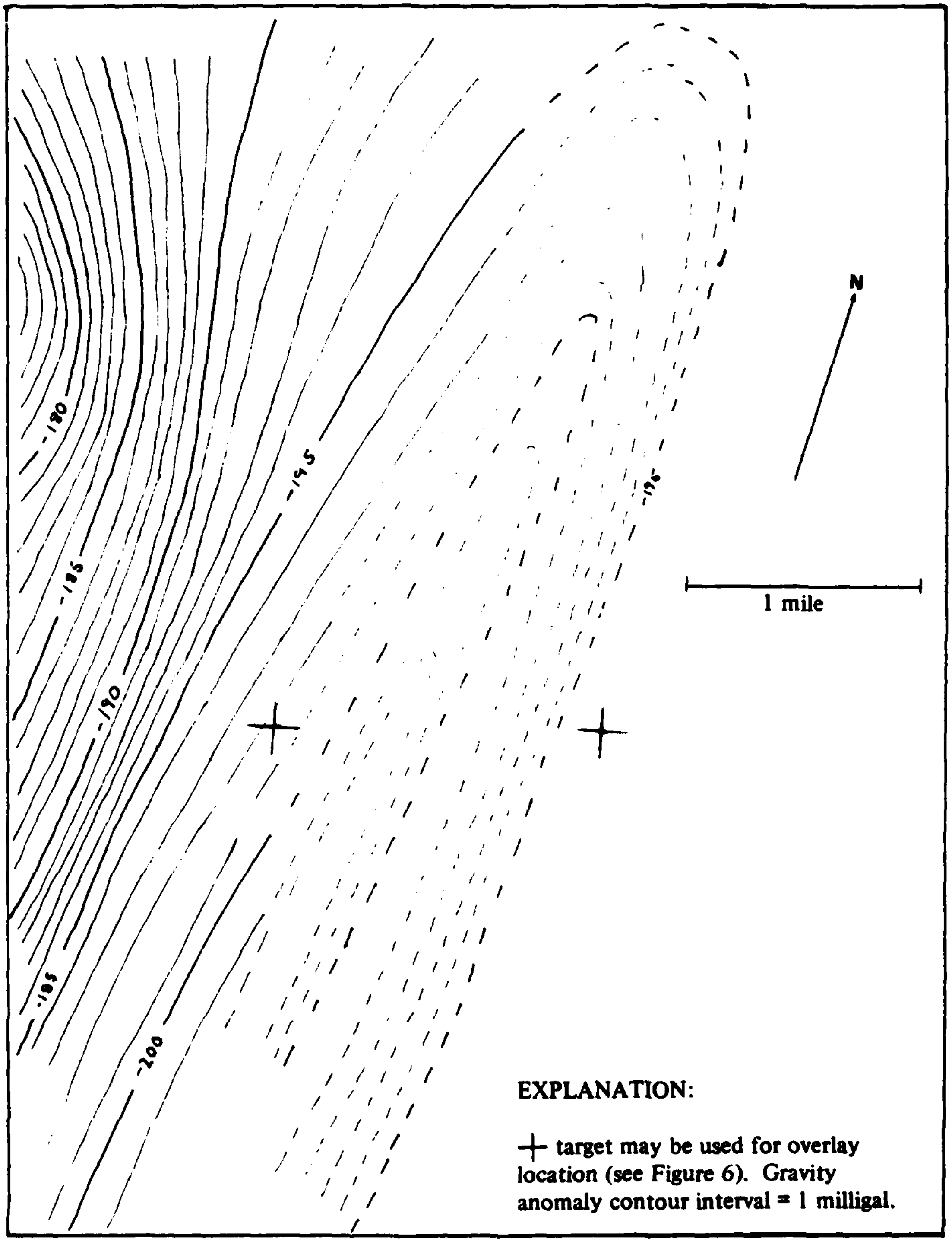
A gravity survey was run over the Sand Springs Mountains and adjacent valleys for the Shoal Project (footnote 1). A complete Bouguer Anomaly Map was prepared. Data from this map are given as Figure 4. Supplemental data were taken from the Reno sheet, Bouguer Gravity Map of Nevada[3]. A complete Bouguer Anomaly Map indicates that terrain corrections were made. Gravity data indicate that the eastern frontal fault separating Fairview Valley and the Sand Springs Mountains is a complex system of northwest and northeast trending faults rather than a simple single fault. This is to be expected.

The maximum depth of valley fill in Fairview Valley is 5,800 feet thick in the center of the valley, about 6 miles south of U.S. Highway 50 (the south edge of the range). The maximum at U.S. Highway 50 is about 5,600 feet.

AEROMAGNETIC SURVEY

An aeromagnetic survey, done for the Shoal Project under the supervision of the Nevada Bureau of Mines and given as Figure 5, indicates the depth of unconsolidated sediments in Fairview Valley as 5,700 feet (footnote 1), a depth within 100 feet of that determined by gravity studies.

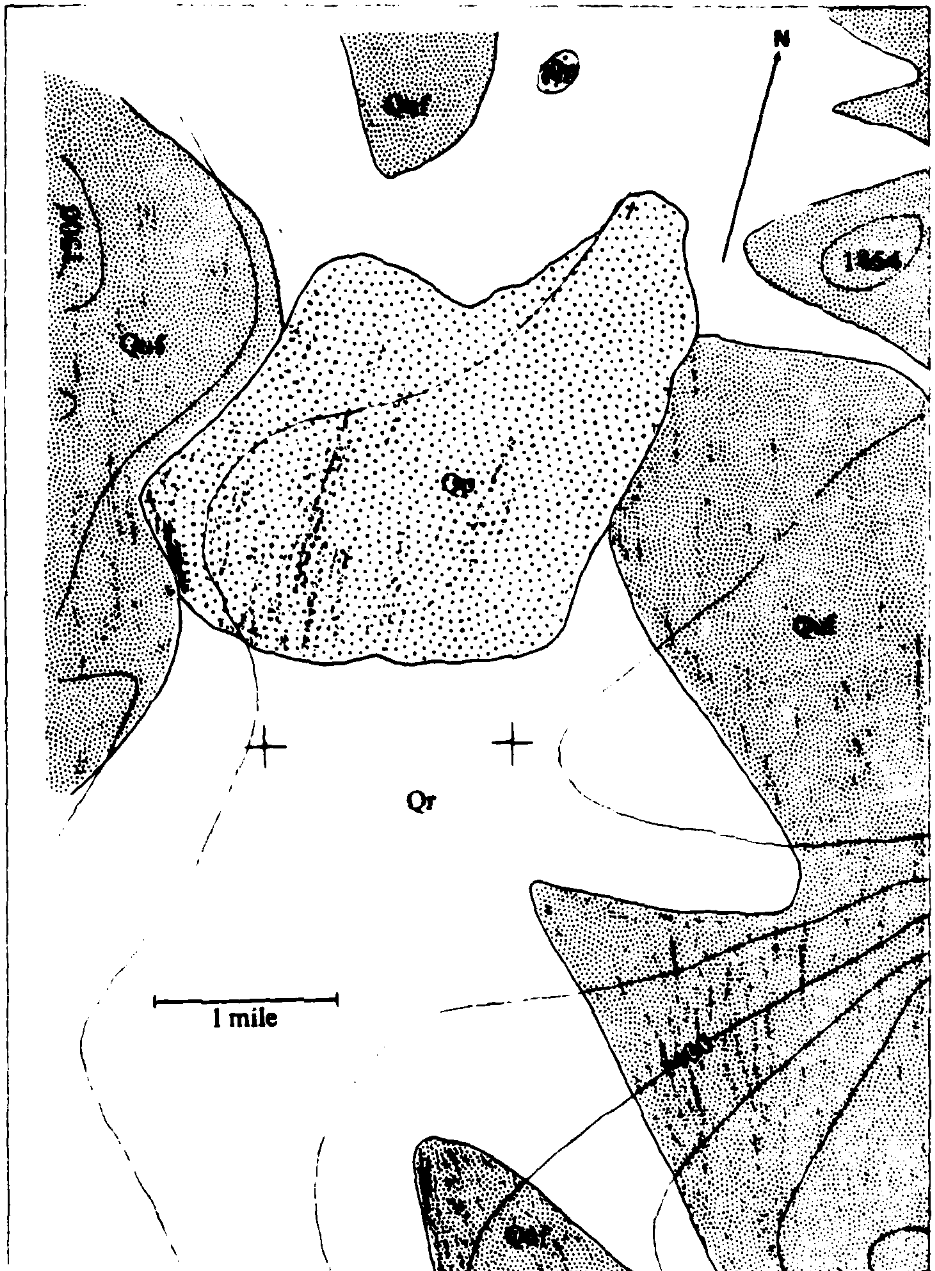
[3]Nevada Bureau of Mines. *Map 58. Bouguer Gravity Map of Nevada, 1977.* Reno, Nev., University of Nevada, 1977. (Publication UNCLASSIFIED.)



EXPLANATION:

+ target may be used for overlay location (see Figure 6). Gravity anomaly contour interval = 1 milligal.

FIGURE 4. Gravity Map of the Sand Springs Mountains and Adjacent Valleys for the Shoal Project. (Solid contours adapted from reference of footnote 2. Dashed contours adapted from Bouguer Gravity Map of Nevada, Reno Sheet, Nevada Bureau of Mines Map 58, 1977.)



EXPLANATION

Target + | Qr | recent alluvium
Geologic contacts — | Qaf | fan deposits
| Qp | playa deposits

Magnetic contours show total intensity of magnetic field in gammas.

FIGURE 5. Aeromagnetic and Geologic Map of Target Area Range Bravo 17. (Adapted from reference of footnote 2.)

SEISMIC REFRACTION STUDIES

A limited seismic study was made in the vicinity of Test Hole HS-1. This study indicated that the fill was compacted at about the elevation of the water table, approximately 310 feet below land surface datum (LSD), and that the depth to bedrock would be greater than 2,000 feet (footnote 1).

THERMAL GRADIENTS AND HEAT FLOW

Thermal gradient data were taken on three holes during Project Shoal. One hole, PM-1, was drilled to a depth of 1,340 feet in granite, near ground zero. The bottom hole temperature was 72°F. This translates to a thermal gradient of 3.0°C/100 m using a mean air temperature of 49.9°F. Normal gradients in the basin and range province are 3.0°C/100 m to 5.0°C/100 m. The curve showed no unusual characteristics (footnote 2, Plate 8).

Data were not available as to the length of time between hole completion and temperature logging. However, if the equilibrium gradient were high, one would expect the measured gradient to be higher than that obtained.

Also as part of the Project Shoal, thermal conductivity of the Sands Springs granite was determined. The four values obtained were 3.6, 3.1, 4.5, and 4.1 Cal/cm-sec-deg x 10^{-3} (footnote 1). The mean value was therefore 3.8 Cal/cm-sec- deg x 10^{-3}. This is considerably lower than the values given by Birch and others[4] for granite. The Shoal investigators attributed this to the granite having well-developed fracture cleavage.

Combining the thermal gradient and conductivity, one obtains a heat flow value of 1.15 Cal/cm^2-sec (heat flow units (HFU)) which is slightly below average for the basin and range province (1.25 HFU).

Gradient data were also measured on the alluvium of Hole H-4 in Fairview Valley and Hole H-3 in Fourmile Flat. The bottom hole temperature of Hole H-3 was 58°F, which gives a gradient of 3.1°C/100 m. Hole H-4 had a bottom hole temperature of 69°F at 975 feet, which gives a gradient of 4°C/100 m.

Hole H-3 had a negative gradient from 329 to 400 feet. Hole H-4 had a negative gradient from 300 to 340 feet. These negative gradients may be caused by shallow ground water.

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[4] Birch, Francis, J.F. Schairer, and H. Cecil Spicer. *Handbook of Physical Constants. Special Papers Number 36.* Boulder, Colo., Geological Society of America, January 1942 (reprinted 1961). 325 pp.

Thermal conductivity was not determined on the alluvium of Fairview Valley as part of Project Shoal. However, work done in 1978[5] provided conductivity data for alluvium in the Monroe-Red Hill Hot Springs areas in Utah. Averaging these later data and converting to centimeter-gram-second(cgs) units would give 1.2 Cal/cm-sec-deg x 10^{-3} for dry alluvium and 3.76 Cal/cm-sec-deg for saturated alluvium; therefore, the heat flow at Hole H-3 would be between 0.35 and 1.17 HFU and at Hole H-4 between 0.45 and 1.3 HFU. The higher values are similar to those obtained for the granite at the Shoal Site.

HYDROLOGY

Extensive hydrologic studies were made for the Shoal test. Data on wells and test holes used for the hydrologic studies are given in Tables 1 and 2. The two holes drilled in Fairview Valley are HS-1 and H-4.

Hole HS-1 was drilled in Quaternary alluvium consisting predominantly of sands with varying amounts of clay, silt, and gravel. Confined water was encountered in sand at a depth of 312.0 feet below the ground surface. Overlying the top of the sand aquifer was approximately 70.0 feet of fine-grained, silty sand. After the hole had been drilled to a depth of 530.0 feet below ground surface, a fine-grained, clayish, silty sand approximately 32.0 feet thick was encountered. This interval serves as an aquitard between the upper and lower aquifers, the latter consisting predominantly of sand with a higher percentage of silt and clay than the upper aquifer.

Test Hole H-4 was drilled in Quaternary alluvium consisting predominantly of sand with varying amounts of clay, silt, and gravel and Tertiary bedrock. Confined ground water was found in sand at a depth of 310.0 feet below ground surface. Overlying the top of the sand aquifer is approximately 65.0 feet of fine-grained, silty sand. After the hole had been drilled to a depth of 530.0 feet below ground surface, a fine-grained, clayish sand approximately 35.0 feet thick was encountered. This interval serves as an aquitard between the upper and lower aquifers.

At a depth of 813.0 feet below the ground surface, a distinct lithologic change was encountered with subsequent changes in the sample color, texture, percentage, and nature of the accessory minerals, along with an increase in drilling time required per foot. The possibility of Tertiary bedrock from 813.0 feet to the bottom of the hole at 935.0 feet exists. Hole H-4 was later plugged at a depth of 708 feet below the ground surface.

The well log of water point 18 (Table 3) was taken from the Sand Springs report (footnote 1). This well log is representative of sediments in the vicinity of Frenchman.

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[5] U.S. Department of Energy. *Geophysical Study of the Monroe-Red Hill Geothermal System*, by W. Mose, D. S. Chapman, and S. H. Ward. Washington, D.C., DOE, 1978. (IDO/76-1601-77-17, publication UNCLASSIFIED.)

TABLE 1. Characteristics of Test Holes and Wells, Sands Springs Range and Fairview Valley.[a]

Designation	Location (U.S. Coast and Geodetic Survey coordinates)	Location (federal land survey)	Elev. collar	Inclination	Vertical depth, ft	Diameter, in.	Use
Sands Springs Range							
ECH-A[b]	N 1,619,292.72; E 558,740.32	NE 1/4; NW 1/4; NW 1/4 Sec 3, T15N; R32E	5158.90	------45°	1342	2.9	Shoal Proj. Test Hole
ECH-D	N 1,619,975.66; E 557,545	SW 1/4; SE 1/4; SW 1/4 Sec 34, T16N, R32E	5238	Vertical	2017	6	Shoal Proj. Test Hole
PM-1	N 1,618,275; E 535,950	SW 1/4; NW 1/4; NW 1/4 Sec 3, T15N, R32E	5364	Vertical	1350	12.5	Shoal Proj. Test Hole
PM-2	N 1,622,985; E 558,200	NE 1/4; SW 1/4; NW 1/4 Sec 34, T15N, R32E	5325	Vertical	1310	12.5	Shoal Proj. Test Hole
PM-3	N 1,619,150; E 559,375	NE 1/4; NW 1/4; NE 1/4 Sec 3 T15N, R32E	5717 (?)	Vertical	1110	12 (to 550 ft) 11.5 (to 1110 ft)	Shoal Proj. Test Hole
PM-8	N 1,619,950; E 557,045	SE 1/4; SW 1/4; SW 1/4 T16N, R32E	5329	Vertical	900		
USBM-1	N 1,619,800; E 557,500	SW 1/4; SE 1/4; SW 1/4 T16N, R32E	5196	Vertical	1430		
Fairview Valley							
H-4	N 1,622,285.67; E 576,914.39	SW 1/4; SW 1/4; NW 1/4 Sec 32, T16N, R33E	42441.92	Vertical	935	6	Shoal Proj. Test Well
HS-1	N 1,622,141.28; E 576,875.65	SW 1/4; SW 1/4; NW 1/4 Sec 32, T16N, R33E	4243.76	Vertical	699	8	Shoal Proj. Test Well
WP-16		SE 1/4; SE 1/4; SW 1/4 Sec 32, T16N, R33E	4262.78	Vertical	364	6	Stock
WP-17		SW 1/4; SE 1/4; NW 1/4 Sec 3, T16N, R33E	4153.3	Vertical	280	6	Domestic
WP-18		SW 1/4; SE 1/2, NW 1/4 Sec 3, T16N, R33E	4153.3	Vertical	288	8	Domestic
WP-19		NE 1/4; NW 1/4; NE 1/4 Sec 11, T17N, R34E	4147.80	Vertical	373	8	Not Used (on Range)
WP-24		SW 1/4; Sec 18, T17N R34E	4217	Vertical	334	6	Stock

[a] From footnotes 1 and 2.

[b] Bearing – N 60° W, depth – 1898 ft.

TABLE 1. (Contd.)[a]

Designation	Discharge, gpm	Pump type	Depth to water, ft	Date	Temp, °F	Date
Sands Springs Range						
FCH-A			Not encountered			
FCH-D			968 1086	7/21/62 8/1/62		
PM-1			1080 1100	3/22/63 7/25/63	See gradient data	
PM-2			715 870	4/24/63 7/22/63		
PM-3			1020 1070	4/23/63 7/25/63		
PM-8			920	7/2/63		
USBM-1			925	8/16/63		
Fairview Valley						
H-4	70	Submersible	299.20	2/18/62	50 (at 320 ft)	4/23/62
HS-1	70	Turbine	300.14	2/17/62	65	4/18/62
WP-16	5	Cylinder (Windmill)	319.20 319.28	4/17/62 7/10/62		
WP-17	15	Submersible	224.10	4/17/72	64	5/16/62
WP-18	17	Submersible	224.60	4/17/62		
WP-19	5	Cylinder	218.84 218.80	7/10/62 4/23/62	60 61	5/22/62 5/22/62
WP-24	10	Cylinder	279.20 299.70	7/10/62 5/9/62		

[a]From footnotes 1 and 2.

TABLE 2. Availability of Logs, and Drill Holes, Sand Springs Range and Fairview Valley[a]

Log	HOLE								
	ECH-A	ECH-D	PM-1	PM-2	PM-3	PM-8	USBM-1	H-4	HS-1
Core or bit size	X	X	X	X	X		X		
Casing	X	X						X	X
Water	X	X	X						
Percent core recovery	X	X	X	X	X				
Condition of core	X	X							
Drilling rate	X	X	X	X	X		X		
Lithology	X	X	X	X	X		X	X	X
Fractures and faults	X	X	X	X	X		X		
Alteration & mineralization	X	X	X	X	X		X	X	
Gamma ray			X	X	X		X	X	
Neutron			X	X	X		X		
Microlaterlog			X	X	X				
Electric:									
Spontaneous potential			X	X	X				
Resistivity			X	X	X				
Grain size-sludge			X	X	X		X		
Caliper			X		X		X		
Gamma gamma density			X	X	X				
Sonic:									
Spontaneous potential			X	X	X				
Interval transit time			X	X	X				
Temperature			X				X		
Fracture finder							X		
Micro seismogram							X		

[a]From footnotes 1 and 2.

TABLE 3. Well Log of Water Point 18.

Depth		Thickness, Feet	Type of Material
From, Feet	To, Feet		
0	30	30	Silt and Sand
30	42	12	Clay
42	55	13	Sand and gravel
55	144	89	Sand and gravel
144	148	4	Coarse gravel
148	170	22	White clay
170	223	53	Sandstone
223	283	60	Sand and silt with thin gravel layers–water encountered at 227 feet
283	288	5	White clay

On 10 March 1962, Test Hole HS-1 was pumped for 20 hours, withdrawing from the interval between 310 feet to 530 feet, and Test Hole H-4 was used for recording observations (footnote 1).

On 5 May, the lower aquifer system (570 feet to 685 feet) at this site was tested using H-4 as a pump well and recording observations in Test Hole HS-1. For details of the test see the first Shoal report (footnote 1), pp. 56-60. Results are summarized in Table 4.

Movement of water in Fairview Valley is from south to north. From hydrologic data for Fairview Valley, the Nevada Bureau of Mines estimates the velocity of movement to be 25 feet or less per year.

Hydrologic data on the Sand Springs granite is harder to interpret. All holes drilled for the test event, except an inclined hole, ECH-A, encountered water.

The permeability of the granite is low (Table 4); however, fracture permeability occurs. A cross section of ground zero showing faults and shear zones is shown as Figure 3. Tests of Hole ECH-D (2,017 feet in depth) indicated that all fractures below a depth of 968 feet are saturated and yield water, but that fractures below 1,355 feet transmit the most water (footnote 1). Bailing tests of the various holes drilled in the granite zone gave rather inconclusive results. Part of the problem was that fractures contained water introduced during drilling. This added water has also complicated the interpretation of water chemistry. The transmissive constant, based on recovery curves after bailing, gave values for PM-1 of 28 to 77 gallons per day per foot (gpd/ft), PM-3 of 19 to 963 gpd/ft and USBM from 61 to 174 gpd/ft. Hole H-3, drilled in granite at Fourmile Flat, east of Sand Springs Range,

TABLE 4. Summary of Aquifer Characteristics, Sand Springs Range and Fairview Valley.[a]

Well and aquifer number	Specific capacity	Pumping test method	Coefficient of transmissibility (T), gpd/ft	Coefficient of storage (S)	Effective thickness, ft	Apparent permeability, gpd/ft
H-4, HS-1 Upper Aquifer	1.8	Drawdown	17,100	2.04×10^{-4}	219	78
H-4, HS-1 Lower Aquifer	2.4	Recovery	11,000	2.45×10^{-4}	120	91
H-3 Bedrock	--	--	>200	--	--	--

	Permeability of Granite, millidarcies x 10^{-6}	Depth, ft
Core Drill Hole, ECH-D	13.8	512
	3100	994
	less than 1	1422
	390	2004

[a]From footnote 2, pp. 75 and 59.

gave values greater than 100 gpd/ft. These values are, of course, low compared with those determined for alluvium on this project, 5,275 to 76,000 gpd/ft (footnote 2), but do indicate that the granite, where fractured, has appreciable permeability.

The Shoal shot raised the water level in Test Hole H-4, in Fairview Valley, 0.036 foot. The water returned to its preshot level within 24 hours. Water levels in holes within the granite rose as much as 65 feet and recovered to normal levels at variable rates.

GEOCHEMISTRY

WATER CHEMISTRY

Water chemistry and geothermometry values of water from six wells and test holes in Fairview Valley and five test holes in the Shoal Site (footnotes 1 and 2) are given in Tables 5 and 6. Unfortunately, the analyses are of poor quality. Of 21 analyses, six do not balance electrically within 20%. There are obvious differences between the same analyses given in parts per million (ppm) in footnote 1 and in equivalents per million in footnote 2. It is not possible to determine which is correct.

In Fairview Valley, the shallow aquifer waters are sodium-calcium-bicarbonate-sulfate waters. Potassium and magnesium are minor, and chloride is the least prevalent anion. The wells of the west side of the valley on the south end of the range produce water of good quality—260 to 282 ppm total dissolved solids (TDS). Well 24 on the west side of the Dixie Valley just north of the range has water of similar composition and quality (334 to 345 ppm TDS).

Water at Frenchman on the north central edge of the range is of poorer quality (664 to 1,014 ppm TDS) and may be characterized by potassium content exceeding calcium content. This could possibly indicate the leakage of geothermal waters into the aquifer. However, a more probable cause is precipitation on calcite as caliche due to evaporation from the playa with a resulting relative increase in potassium content. The waters of the playa dissolved solids from the alluvium as they moved from the edge of playa to the center and from the south to the north.

Chemical geothermometers exhibit great scatter (Table 5). Using only the analyses which electrically check within 20%, the mean silica reservoir equilibration temperature for the alluvial waters is 90°C and the Na-K-Ca temperature is 107°C. Using all of the available analyses, the silica temperature becomes 92°C and the Na-K-Ca temperature becomes 134°C.

TABLE 5. Composition of Water; Shoal Site, Sand Springs Range, and Fairview Valley.[a]

Item[b]	HS-1	HS-1	HS-1	H-4 shallow aquifer	H-4 deep aquifer	PM-1	PM-2	PM-3	ECH-D top sample	ECH-D middle sample
Date of sample	4/4/62	11/26/63	2/1/64	P5/28/62	P7/11/62	P5/29/63	P5/29/63	P5/29/63	P7/19/62	P7/19/62
pH	7.4	8.2	8.1	7.9	8.0	8.4	7.3	8.2	8.1	8.2
TDS,(ppm)	282	262	283	265	338	1300	622	620	363	398
SiO_2, (ppm)	38	58	67	51	59	19	3	54	24	13
Equivalents										
per million	2.30	2.26	2.18	2.64	2.98	2.26	6.62	1.40	3.96	2.36
HCO_3 as $CaCO_3$										
CO_3 as $CaCO_3$	- -	0.02	0.12	0.02	0.20	0.02	0.12	0.04	0.16	0.16
NO_3^-	NA	NA	0.04	NA	NA	NA	NA	NA	NA	NA
Cl^-	1.22	1.24	1.89	0.62	0.79	19.8	2.20	0.64	2.99	3.21
SO_4	0.89	1.12	1.06	0.81	0.87	2.70	1.62	1.27	1.77	2.04
Total anions	4.41	4.64	5.29	4.09	4.84	24.78	10.56	3.35	8.88	7.77
Na^+	3.35	2.00	2.00	4.70	2.17	11.81	3.05	17.80	3.53	3.21
K^+	0.85	0.18	0.18	0.23	0.12	0.23	0.23	0.46	0.13	0.10
Ca^+	1.34	1.60	1.54	1.34	1.64	5.60	4.34	3.55	3.89	4.14
Mg^+	0.33	0.25	0.45	0.25	0.41	4.03	0.91	0.41	0.58	0.82
Fe^+	0.14	0.07	- -	0.11	0.14	0.04	0.04	0.18	0.04	0.04
Total cations	6.01	4.10	4.17	6.63	4.48	21.71	8.57	22.50	8.17	8.31
Remarks[c]	PS-A	PS	PS	PS-A	PS	BS	BS-A	BS-A	PS	PS
SiO_2 temp.°C[d]	91	106	112	107	107	70	35	103	76	61
Na-K-Ca temp.,°C[d]	252	83	69	90	44	69	60	143	97	80

General note: NA = not analyzed; BS = bailed sample; PS = pumped sample; A = probable analytical errors.

[a] From footnote 2, pp. 305 and 306.

[b] Hanks TDS at 600°C: data given in ppm; silica data in ppm; all other data in equivalents per million.

[c] All analyses by Hanks Laboratory except for HS-1, WP-18 (d), and WP-24, which were Hazelton-Nuclear Science Corporation, Los Angeles, California, and Las Vegas, Nevada (HNSC).

[d] Calculated by Geothermal Technology Branch, Public Works Department, Naval Weapons Center, China Lake, California.

TABLE 5. (Contd.)[a]

Item[b]	ECH-D Bottom Sample	ECH-D	USBM-1	WP-16	WP-17	WP-18(a)	WP-18(b)	WP-18(c)	WP-18(d)	WP-24	WP-24
Date of sample	P7/19/62	7/16/62	7/2/63	4/1/62	4/6/62	P8/1/62	P10/16/63	11/26/63	1/30/64	P5/28/62	1/30/64
pH	8.1	8.5	8.0	7.4	7.6	8.3	8.5	8.6	8.4	8.2	7.8
TDS, ppm	400	388	463	260	918	990	1096	644	1014	334	345
SiO_2, ppm	15	49	31	50	50	70	40	14	65	29	35
Equivalents per million HCO_3 as $CaCO_3$	2.40	3.68	2.36	2.32	7.82	9.50	8.36	8.78	8.44	2.24	2.22
CO_3 as $CaCO_3$	0.10	0.30	0.02	- -	0.02	0.68	0.12	0.14	0.32	0.02	- -
NO_3^-	NA	NA	NA	NA	NA	NA	NA	NA	0.01	NA	0.06
Cl^-	3.39	2.83	2.82	7.92	4.00	3.70	5.64	2.42	3.58	2.00	2.20
SO_4	1.88	1.91	3.35	0.88	3.88	3.84	8.12	3.73	3.92	1.21	1.21
Total anions	7.77	8.71	8.55	11.12	15.72	17.72	22.24	15.07	16.27	5.47	5.69
Na^+	3.35	3.74	4.53	3.30	20.65	15.00	17.75	10.73	14.80	6.05	4.52
K^+	0.21	0.23	0.10	0.64	0.95	0.46	0.26	0.26	0.26	0.15	0.16
Ca^+	3.94	3.12	2.75	1.20	0.50	0.45	1.80	2.19	0.48	0.80	0.67
Mg^+	0.58	0.82	0.41	0.49	0.33	0.25	0.33	0.16	0.27	0.08	0.80
Fe^+	0.11	0.11	0.11	0.21	0.32	0.05	0.11	0.05	0.01	0.16	- -
Total cations	8.19	8.02	7.90	5.84	22.75	16.21	20.25	13.39	15.82	7.24	6.15
Remarks[c]	PS	Air Lift Sample HA	BS	PS-A	PS	PS	PS	PS	PS	PS-A	PS
SiO_2 temp., °C[d]	64	100	84	100	100	114	140	62	111	82	88
Na-K-Ca Temp., °C[d]	178	180	49	234	192	170	123	92	138	90	79

General note: NA = not analyzed; BS = bailed sample; PS = pumped sample; A = probable analytical errors.

[a] From footnote 2, pp. 305 and 306.

[b] Hanks TDS at 600°C. data given in ppm; silica data in ppm; all other data in equivalents per million.

[c] All analyses by Hanks Laboratory except for HS-1, WP-18(d), and WP-24, which were HNSC.

[d] Calculated by Geothermal Technology Branch, Public Works Department, Naval Weapons Center, China Lake, California.

TABLE 6. Analyses of Waters From Drill Holes and Wells, Fairview Valley and Sand Springs Range.

Item	HS-1	HS-1[a]	HS-1[a]	H-4 shallow aquifer	H-4 deep aquifer	PM-1[a]	PM-2[a]	PM-3[a]	ECH-D top sample	ECH-D middle sample	ECH-D bottom sample
Date of sample	4/4/62	1/26/63	2/1/64	P5/28/62	P7/11/62	P5/29/63	P5/29/63	P5/29/63	P7/19/62	P7/19/62	P7/19/62
pH	7.4	8.2	8.1	7.9	8.0	8.4	7.3	8.2	8.1	8.2	8.1
TDS, ppm	282	262	283	265	338	1300	622	620	363	398	402
Ca	27	32	44	27	33	112	87	71	78	83	79
Mg	4	3	5	3	5	49	11	5	7	10	7
Na	77	46	46	108	50	272	70	409	81	74	77
K	33	7	7	9	3	9	9	18	5	4	8
Fe	4	2	--	3	-1	4	1	5	1	1	3
SiO_2	58[b]	58	67	51	59	19	3	54	24	13	15
SO_4	53[c]	54	51	39	42	130	78	61	85	98	90
Cl	43	44	67	22	28	702	78	23	106	114	120
CO_3 as $CaCO_3$	--	1	6	1	10	1	6	2	8	8	5
HCO_3 as $CaCO_3$	115	113	109	132	149	113	331	70	198	168	170

[a] *Calculated from* equivalent part per million (footnote 2, pp. 305-306), by the Geothermal Utilization Division, Public Works Department, Naval Weapons Center, China Lake, California.

[b] Value *from* footnote 1, p. 126. The value given in footnote 2, p. 305, is 38 ppm.

[c] A value of 53 was reported in footnote 1, p. 126. A value of 43 was obtained by calculation of equivalents from *footnote 2, p.305.*

TABLE 6. (Contd.)[a]

Item	ECH-D Total Sample	USBM-1a	WP-16	WP-17	WP-18	WP-18[a]	WP-18[a]	WP-18[a]	WP-24	WP-24[a]
Date of sample	7/16/62	7/2/63	4/1/62	4/6/62	P8/1/62	P10/16/63	11/26/63	1/30/64	P5/28/62	1/30/64
pH	8.5	8.0	7.4	7.6	8.3	8.5	8.6	8.4	8.2	7.8
TDS, ppm	338	463	260	918	990	1096	644	1014	334	345
Ca	63	55	24	10	9	36	44	10	16	13
Mg	10	5	6	4	3	4	2	3	1	10
Na	86	104	76	475	345	408	247	340	139	104
K	9	4	25	37	18	10	10	10	6	6
Fe	2	3	4	6	1	9	1	0.3	3	--
SiO_2	49	31	50	50	70	40	14	65	29	35
SO_4	92	161	42	186	184	390	179	188	58	58
Cl	100	100	281	142	131	200	86	127	71	78
CO_3 as $CaCO_3$	15	1	--	0.8	34	6	7	16	1	--
HCO_3 as $CaCO_3$	184	118	116	391	475	418	439	422	112	111

[a] Calculated from equivalent parts per million (footnote 2, pp. 305-306) by Geothermal Utilization Division, Public Works Department, Naval Weapons Center, China Lake, California.

The waters of the deep aquifer in Fairview Valley at Hole H-4 are chemically similar to those of the shallow aquifer with 338 ppm TDS. These waters give a silica temperature of 107°C and a Na-K-Ca temperature of 44°C.

Interpretation of the chemistry of waters from the Sand Springs granite is difficult. Water from HS-1 was used in drilling the test holes, and large quantities of water were lost. The holes were sampled almost immediately after drilling, so the waters were probably badly contaminated by drilling fluids. As noted earlier, HS-1 produced water of good quality with a low content of dissolved solids. The waters from the granite contained 363 to 1,300 ppm TDS. In general, the bicarbonate content exceeded the chloride content which exceeded the sulfate content. Hole PM-1 is an exception in that chloride exceeded bicarbonate. This could possibly indicate leakage from a geothermal reservoir, but the general poor quality of the analyses, coupled with the complete lack of other geothermal manifestations in the area, makes this interpretation doubtful. Sulfate is the predominate anion in the waters from Hole USBM-1, which could represent contamination from geothermal vapor; but again, considering the contaminated samples, the poor quality of analyses, and the lack of other indicators of geothermal potential, the writers do not feel such an interpretation is justified.

Silica temperatures of the analyses of waters from the Sand Springs granite, which balance electrically, range from 61°C to 100°C with a mean of 75°C. If all of the analyses are used, they range from 35°C to 103°C with a mean of 74°C.

Na-K-Ca temperatures of the better analyses range from 49°C to 180°C with a mean of 106°C. If all of the analyses are averaged, the mean is 107°C.

MERCURY GEOCHEMISTRY

Soil Sampling

As part of the geothermal exploration program, soil samples were collected on Range Bravo 17, on 7 February 1979, for subsequent mercury analyses. The sampling was performed by personnel of the Geothermal Utilization Division (John Bown, Jack Neffew, Ron Collins, and C. R. Rodgers) and assisted for safety reasons by naval Explosive Ordnance Disposal (EOD) personnel. Analyses of the samples collected are discussed in a later section of this report.

Sixty-three samples were collected along five traverses laid out along approximate north-south bearings. Traverse "A" started at the south end of what is known locally as the "airstrip" and extended north to U.S. Highway 50. Traverse "B" started at U.S. Highway 50 and ran south along the eastern flight line through the bullseye to the south boundary of the range. Traverse "C" ran along the centerline road from the north fence to the end of the road. Traverse "D" extended from the north fence south to the target along the

western flight line. Traverse "E" extended from the intersection of U.S. Highway 50 and Nevada 31 south along Nevada 31 for about 4 miles. The traverses were 0.5 to 1 mile apart. Samples were taken at 0.3 mile intervals using vehicle odometers. The traverses were partially staked.

On the advice of Mr. James Anderson, a geochemist with Pacific Energy and Minerals, Golden, Colorado, the top-most layer of soil was sampled. Loose gravel, snow, and organic matter were brushed away, and several ounces of soil were collected with plastic scoops and put into airtight plastic vials. Individual samples were labeled with a letter and a number.

Several problems hampered the sampling program at Range Bravo 17. No adequate map or recent aerial photograph seems to exist for this range. Because this is an active bombing range, certain areas could not be sampled for safety reasons. Also, only about one-third to one-half of the range was covered, since the eastern portion of the area reaches elevations over 8,000 feet and was not accessible due to a heavy snow cover. The final problems were also weather related. After a long period of freezing weather, a thaw had begun several days before sampling was performed. According to experts, a heavy snow melt or rainfall will lower the mercury content of soil. Also, the thaw caused several areas to become impassible due to mud.

Sample Preparation

The soil samples from Range Bravo 17 were damp to wet when collected; on return to the Naval Weapons Center, they were dried overnight at 125°F. After drying, the samples were screened through an 80-mesh stainless steel screen (180 micrometers, 0.007 inch) and stored in 76-cc plastic bottles prior to mercury determinations. Several samples, primarily the clays, had to be crushed prior to screening to provide sufficient sample for analysis. The samples were either (1) quartz sands or (2) silts and clays.

Mercury Analysis

Range Bravo 17 soil samples were analyzed for mercury content using Thermotron Corporation's atomic absorption mercrometer in conjunction with a mercury collector unit. This unit collects the mercury vapor on silver wool, allowing extraneous gaseous materials to flow through the equipment prior to the mercury vapor count. The instrument is calibrated by injecting a known quantity of mercury vapor into the collector unit and noting the readout. For example, 1 cc of mercury vapor at 26°C contains 21.52 ng (10^{-9} gram) of mercury and might read 73 counts, each count being 21.52/73 or 0.295 ng per count.

In operation, the soil sample is weighed and placed in a quartz tube for heating. The gases, including the mercury vapor, are driven off the sample by heating between 650 and 799°C. (Nitrogen gas at 250 ml/min is used as the carrier fluid.) They then flow through water vapor and acid gas filters into the mercury collector unit where

the mercury vapor is absorbed on Collector A (the first of two silver wool collectors, A and C). Extraneous gases flow on through the instrument and are exhausted. Collector B is then heated, which drives the mercury vapor off and deposits it on Collector C. The mercrometer is then balanced to zero and the mercury vapors are driven off by heating Collector C. The imbalance between the detection cell and reference cell is displayed on the digital readout.

The Range Bravo 17 samples were run through twice. The first series was run using only the mercrometer, because the collector unit had been contaminated with a high mercury content sample. The tubes containing the silver wool were removed from the collector unit and baked out by the Chemistry Division at NWC, but since the series had been started with a particular setup, the collector unit was not put into operation until the first series was completed.

Duplicate, or additional, samples were run on both the first and second series. The first series produced mercury counts which were more tightly grouped than the second series, which was run using the collector unit. The instrument designer, Mr. Thomas Dooly (formerly with Thermotron Corporation), pointed out that calibrations made by directly injecting mercury vapor into the detection cell may be in error because the injection rate is unknown and the count is dependent on the percentage of mercury vapor in the cell. When the collector unit is used, however, the mercury vapor is driven off at a specific rate and is carried into the detection cell by a known and reasonably invariable quantity of air or nitrogen. The same reasoning applies to the sample if the gases from the sample (which are released at different temperatures) are led directly into the detection cell. For this reason, the use of the collector unit should result in more accurate calibrations and results.

Therefore, the second run was made using the collector unit in combination with the detector unit. About half-way through the samples, it was discovered that residual counts would show up if the collector unit was cycled without a sample or with the old sample still in the sample tube. Furthermore, the number of residual counts varied depending on the time selected for recycling. The run was completed recording both sample counts and periodic residual counts. The residual count varied slightly but usually was in the range from 6.5 to 11 counts with sample counts measuring from 6.8 to 11. Actually, the residuals could probably be ignored at these levels since they correspond to only 1.37 and 3.2 ng, respectively.

Computations

The quantity of mercury vaporized from each sample is calculated as nanograms of mercury per gram of sample. The calculation is made as follows: determine the quantity of mercury per calibration count and mutiply this number by the number of counts obtained on running the sample to obtain nanograms mercury per gram of sample weight. In practice, the residual counts are subtracted from both the calibration and run counts before the calculation is made.

EXAMPLE:

Suppose the sample count is 28 for a 0.5 gram sample, the residual count is 8.0, and the calibration count is 62 with a mercury temperature of 20.0°C. Looking at the vapor-temperature table for mercury, 1 cc contains 13.19 ng which was injected into the mercury analyzer. Assuming that the counts are high by 8, subtract 8 from 28 and 62. Therefore:

$$\frac{13.19 \times (28 - 8)}{(62 - 8) \times 0.5} = 9.77$$

$$= 9.77 \times 10^{-9} \text{ grams Hg/gram sample}$$

Results

Results are given in Figure 6. The median value for mercury content is 8.85; the mean value is 9.7; the standard deviation is 4.1. Using two standard deviations as threshold value, the threshold would be 17.9. Only four samples exceeded the threshold and they produced one point anomalies.

Comparing the isoconcentration map with the geologic map, it appears that the deposits and younger alluvium are very low in mercury, while the alluvial fans coming off the mountains are somewhat higher in mercury content.

CONCLUSIONS

The geothermal potential of the Shoal area and Range Bravo 17 is considered low for the following reasons:

1. Thermal gradients in both areas are low.
2. Heat flow in both areas is low.
3. No hot or warm wells or springs occur in the areas, nor are there any fossil hot springs.
4. No hydrothermal alteration or mineralization of the type generally associated with geothermal resources was noted in the areas.
5. The silica and Na-K-Ca chemical geothermometers do not indicate that the waters have recently been in equilibrium with rocks at elevated temperatures.
6. The mercury content of the solid material of Fairview Valley is very low.
7. The valley fill in Fairview Valley is 5,800 feet deep. A geothermal resource, if present, would be very deep.

Because of the above-listed factors, further exploration at the Shoal Site and Fairview Valley is not warranted at this time.

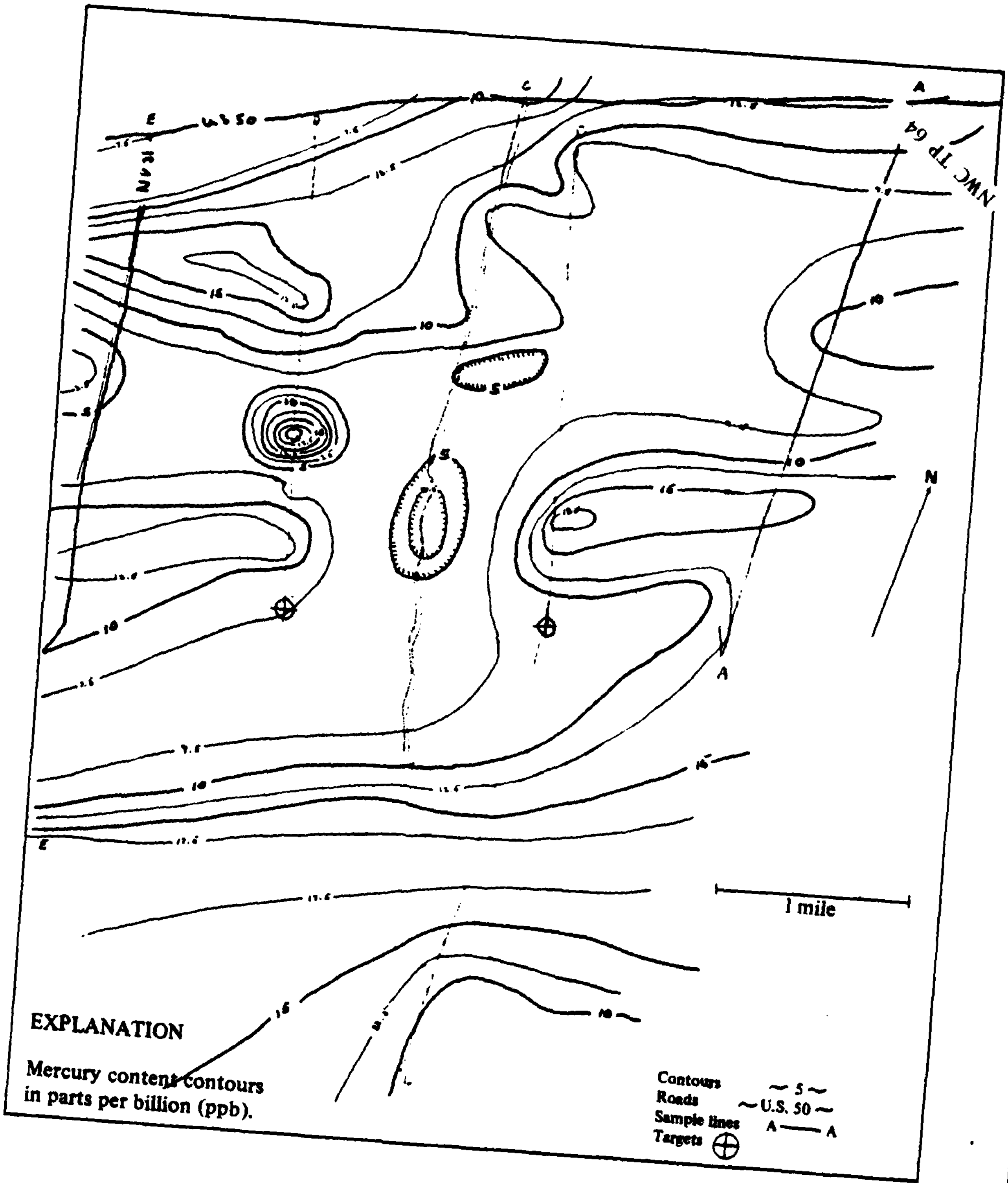

FIGURE 6. Mercury Content in Soils, Range Bravo 20, NAS Fallon.

Appendix A

STATION CLIMATIC SUMMARY

STATION CLIMATIC SUMMARY

PREPARED BY THE NAVAL WEATHER SERVICE ENVIRONMENTAL DETACHMENT, ASHEVILLE, N.C.
BY DIRECTION OF THE COMMANDER, NAVAL WEATHER SERVICE COMMAND

NARRATIVE SUMMARY

The Naval Air Station Fallon, Nevada is located 50 miles east of Reno. The terrain is largely sagebrush and desert. Numerous dry lakes dot the area. The mountains that surround Fallon act as a barrier to the influx of warm moist air from the Pacific Ocean. The Sierra range modifies approaching frontal systems so that they pass over Fallon with the moisture content and temperature markedly reduced.

November marks the beginning of the winter season which lasts until March. Cloudiness and cool temperatures predominate. Cold fronts often provide little more than gusty winds and scattered to broken clouds. Zonal flow during the winter months produces fast moving low pressure systems with abundant moisture, resulting in severe turbulence and icing over the Sierra Nevada's.

Precipitation averages .4 inches during the winter months usually as light showers. Snowfall exceeding 2 inches is extremely rare. Comparatively warm maximum temperatures melt the snow in a day or two. Fog is an occasional problem in restricting visibilities, but rarely persists beyond the morning hours. December and January are the months of greatest fog frequency, occurring on an average of 4 days.

Winter storm tracks are generally located to the north of Fallon and spring like weather prevails. Occasionally a storm brings deteriorating conditions with freakish snowfalls and freezing temperatures.

May marks the beginning of summer which lasts until September. During the summer, hot dry weather dominates. Thunderstorms typically develop late in the afternoon in the foothills to the south. Strong gusty winds associated with these thunderstorms occasionally obscure visibilities with blowing dust. For the most part, these storms are confined to the surrounding foothills and rarely pass directly over the station. Dustdevils are quite frequent during the day over the alkali and sand flats. Only in July and August is the temperature consistently in the 90 degree range. Low humidity prevails through the summer which reduces the effects of high temperatures. Afternoon thunderstorms are primarily responsible for a summer average rainfall of .5 inches.

FALLON, NEVADA

MEAN TEMPERATURE °F

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1945			61.2	60.9	70.5	80.1	77.1	75.0	63.6	55.7	41.0	36.6	M
1946	42.7	50.0	M	M	M	M	M	M	M	M	M	M	M
1947	M	M	M	M	M	M	M	M	M	M	M	M	M
1948	M	M	M	M	M	M	M	M	M	M	M	M	M
1949	M	M	M	M	M	M	M	M	M	M	M	M	M
1950	M	M	M	M	M	M	M	M	M	M	M	M	M
1951	M	M	M	M	M	M	M	M	M	M	M	M	M
1952	M	M	M	M	M	M	M	M	M	M	M	M	M
1953	M	M	M	M	M	M	M	M	M	M	M	M	M
1954	M	M	M	M	M	M	M	M	M	M	46.3	38.7	M
1955	37.1	37.5	40.0	49.0	56.0	60.0	73.0	77.5	65.0	55.5	40.0	38.7	51.9
1956	37.3	35.6	45.3	51.0	55.0	66.6	M	71.0	57.0	52.6	38.3	31.0	M
1957	37.5	42.0	45.5	53.0	56.3	71.0	75.9	72.2	67.1	65.5	37.0	35.7	53.0
1958	36.3	44.3	43.1	49.7	65.0	68.3	75.9	78.6	65.5	55.0	41.0	39.3	53.0
1959	37.0	37.0	45.6	54.0	55.5	70.0	78.4	72.7	61.0	55.1	40.7	37.0	53.3
1960	30.4	35.3	47.6	51.4	57.5	73.0	78.1	73.1	67.0	53.1	42.1	33.1	53.3
1961	32.9	41.6	43.0	50.6	57.5	73.0	77.2	75.5	60.5	53.4	37.3	33.0	53.0
1962	20.4	35.0	40.0	55.3	56.0	68.8	76.2	77.9	66.2	55.7	43.3	36.2	52.3
1963	20.9	47.2	43.3	47.3	61.5	65.2	72.7	73.1	68.7	57.5	41.4	35.1	52.5
1964	33.4	34.1	33.3	44.2	56.6	64.5	75.6	73.1	61.0	57.3	36.3	36.1	51.6
1965	36.3	37.5	42.6	51.9	55.6	64.0	73.0	73.0	50.7	56.3	46.2	37.0	52.2
1966	33.3	35.6	45.0	53.1	59.6	67.7	73.1	75.0	65.6	52.1	44.5	37.7	53.3
1967	36.1	39.5	45.0	42.9	53.0	65.0	78.1	75.0	60.0	56.1	45.2	37.6	53.5
1968	32.2	44.3	45.0	40.0	59.2	69.5	70.3	69.5	64.2	55.2	41.2	31.9	53.1
1969	37.5	37.0	42.1	51.7	63.0	66.7	77.1	76.2	69.7	44.6	40.3	35.3	53.0
1970	37.4	44.0	43.0	49.6	59.3	66.7	77.4	77.0	62.0	52.7	40.0	36.2P	M
1971	37.3	41.3P	47.0P	51.2P	59.7	66.7	78.6P	78.8P	M	49.7	M	35.1P	M
1972	37.5	45.2P	46.0	44.7	62.5P	60.2	74.5	75.1P	59.5	49.7	40.2	36.9P	M

TOTAL PRECIPITATION INCHES

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1945			0.00	M	M	M	M	T	T	0.05	0.10	0.62P	M
1946	0.10	M	M	M	M	M	M	M	M	M	M	M	M
1947	M	M	M	M	M	M	M	M	M	M	M	M	M
1948	M	M	M	M	M	M	M	M	M	M	M	M	M
1949	M	M	M	M	M	M	M	M	M	M	M	M	M
1950	M	M	M	M	M	M	M	M	M	M	M	M	M
1951	M	M	M	M	M	M	M	M	M	M	M	M	M
1952	M	M	M	M	M	M	M	M	M	M	M	M	M
1953	M	M	M	M	M	M	M	M	M	M	M	M	M
1954	M	M	M	M	M	M	M	M	M	M	0.20	0.37	M
1955	0.22	0.36	0.12	0.17	0.63	T	0.03	0.30	0.30	0.21	0.90	1.07	4.47
1956	1.33	T	T	0.05	0.94	0.39	M	0.00	0.91	0.30	0.09	T	M
1957	0.90	0.62	0.31	1.03	0.83	T	0.13	T	0.06	0.96	0.57	0.07	5.69
1958	0.12	0.36	0.23	0.26	0.30	1.64	0.30	T	0.36	0.37	0.16	0.11	3.70
1959	T	0.37	T	T	0.42	0.00	0.02	1.70	0.22	0.60	0.30	0.03	2.90
1960	0.09	0.30	0.12	0.04	0.72	T	0.33	T	0.03	0.01	0.91	0.42	2.03
1961	0.23	0.22	0.90	0.05	0.42	0.30	0.24	1.20	0.46	0.23	0.46	0.24	4.77
1962	0.49	2.27	0.75	0.01	1.70	0.46	0.91	T	T	T	0.10	T	6.01
1963	0.31	0.01	0.43	1.10	0.49	1.44	0.00	0.39	0.60	0.00	0.30	0.58	6.00
1964	0.10	0.16	0.97	0.46	1.57	0.75	0.03	0.19	0.00	0.24	0.10	0.37	4.13
1965	0.42	0.16	0.41	1.07	1.13	0.77	0.30	0.00	0.20	0.03	1.90	0.37	7.04
1966	0.36	0.27	0.00	0.17	0.30	0.49	0.01	0.04	0.37	0.07	[illegible]	1.20	5.31
1967	0.33	0.05	0.06	1.13	0.27	1.36	0.32	0.27	1.00	0.01	0.01	T	7.20
1968	0.40	1.00	0.23	0.07	0.36	0.63	0.13	0.01	T	0.25	0.02	0.50	5.35
1969	1.00	1.11	0.10	0.25	0.32	1.41	0.02	T	0.01	0.46	0.03	0.02	6.40
1970	0.08	0.20	0.25	0.06	0.11	1.49	0.03	0.21	T	T	0.30	0.20	4.23
1971	0.91	0.50	0.41	0.27	1.31	0.23	0.34	0.19	M	0.09	0.21	0.09P	M
1972	0.12	0.04	T	0.17	0.24	1.36	0.07	0.17	0.06	2.26	0.90	0.20	6.18

MONTHLY AND SEASONAL DEGREE DAYS

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
44-45									763	473	220	102	M
45-46	3	8	101	309	697	943	1061	756	M	M	M	M	M
46-47	M	M	M	M	M	M	M	M	M	M	M	M	M
47-48	M	M	M	M	M	M	M	M	M	M	M	M	M
48-49	M	M	M	M	M	M	M	M	M	M	M	M	M
49-50	M	M	M	M	M	M	M	M	M	M	M	M	M
50-51	M	M	M	M	M	M	M	M	M	M	M	M	M
51-52	M	M	M	M	M	M	M	M	M	M	M	M	M
52-53	M	M	M	M	M	M	M	M	M	M	M	M	M
53-54	M	M	M	M	M	M	M	M	M	M	M	M	M
54-55	M	M	M	M	816	1215	[illegible]	[illegible]	[illegible]	376	272	44	M
55-56	4	3	187	285	761	[illegible]	858	[illegible]	612	356	196	51	[illegible]
56-57	M	3	30	392	871	1096	1162	[illegible]	676	430	220	21	M
57-58	2	12	31	442	822	907	952	575	[illegible]	490	75	67	9121
58-59	3	3	41	295	609	[illegible]	863	760	678	333	[illegible]	7	6723
59-60	0	70	192	307	790	1085	1376	855	567	467	256	3	5676
60-61	3	10	41	376	600	953	905	855	653	430	203	17	[illegible]
61-62	3	3	159	308	832	993	1190	[illegible]	764	273	[illegible]	50	5703
62-63	4	5	62	263	652	956	1104	554	713	352	167	115	5205
63-64	7	4	50	297	760	900	[illegible]	[illegible]	767	576	294	95	5522

MONTHLY AND SEASONAL DEGREE DAYS

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
64-65	2	17	100	290	610	836	890	771	752	592	321	80	[illegible]
65-66	3	2	196	280	525	857	976	826	593	350	[illegible]	67	6070
66-67	3	8	40	357	676	1012	895	[illegible]	656	696	203	87	[illegible]
67-68	[illegible]	3	17	332	595	1076	1010	500	595	480	196	53	6005
68-69	[illegible]	46	126	265	716	1020	842	783	[illegible]	413	[illegible]	[illegible]	[illegible]
69-70	[illegible]	[illegible]	[illegible]	300	[illegible]	[illegible]	[illegible]	816	682	557	106	50	[illegible]
70-71	[illegible]	[illegible]	135	[illegible]	545	M	[illegible]	M	M	M	102	35	M
71-72	M	M	4	327	M	M	1156	[illegible]	498	304	M	12	M
72-73	3	4	100	676	[illegible]	M							M

The Degree Day total for the month is the sum of the departures of the daily mean temperatures from the base of 65°F.

M indicates missing record. P denotes partial record, i.e. less than 10 days record missing.

PREPARED BY: NWSED ASHEVILLE STATION NAME: FALLON, NEVADA PERIOD: MAR 45-DEC 72 STN LTRS: KNFL
APRIL 1973 LOCATION : N39 25 W118 42 ELEV : 3934 WBAN # : 93102
WMO # :

	TEMPERATURE DEG F: MEAN DAILY MAX	MEAN DAILY MIN	MEAN MON	EXTREMES MAX	EXTREMES MIN	PRECIPITATION INCHES MONTH MEAN	MONTH MAX	MONTH MIN	MAX 24 HRS	SNOWFALL MN	SNOWFALL MAX	SNOWFALL MAX 24 HR	RELATIVE HUM LST 04	RELATIVE HUM LST 13	VAP PRESS IN OF HG	DEW PT DEG F	PRESS ALT FEET 99.95%	SFC WINDS PVLG DRCTN	SFC WINDS SPEED MN	SFC WINDS SPEED MAX	MEAN AMT CLD IN TENTH	PRECIP INCHES .01 OR GTR	PRECIP INCHES .5 OR GTR	SNOWFALL .1 OR GTR	SNOWFALL 1.5 OR GTR	THUNDERSTORMS	VSBY FOG < 7MI	MAX DEG F > 90	MAX DEG F > 75	MIN DEG F < 32	MIN DEG F < 00
JAN	45	20	33	72	-11	.4	1.7	#	.5	2	7	5	79	51	.12	22	4350	S	4	53	6	4	0	1	#	#	6	0	0	27	1
FEB	51	26	39	73	5	.5	2.4	#	.8	2	10	3	78	45	.14	25	4450	S	5	52	5	4	0	2	#	0	2	0	0	22	0
MAR	58	30	44	82	3	.3	1.0	#	.5	3	21	18	68	34	.13	24	4450	S	6	50	5	3	0	2	#	#	1	0	2	20	0
APR	64	35	50	88	16	.4	1.1	#	1.0	1	8	3	64	29	.15	28	4600	N	6	52	5	3	0	1	#	#	1	0	5	11	0
MAY	74	44	59	95	23	.7	1.7	#	.9	#	7	6	64	28	.20	34	4300	W	6	47	5	4	0	#	#	3	#	1	16	2	0
JUN	84	52	68	104	33	.7	1.6	#	1.0	0	0	0	60	24	.24	39	4250	WNW	5	47	3	4	0	0	0	2	#	9	24	0	0
JUL	93	59	76	105	43	.2	.6	#	.5	0	0	0	55	19	.28	43	4100	WNW	5	62	2	2	0	0	0	3	#	23	31	0	0
AUG	91	57	74	104	37	.3	1.8	#	1.8	0	0	0	55	20	.26	41	4150	WNW	4	48	2	2	0	0	0	2	#	21	30	0	0
SEP	81	48	65	103	24	.4	1.9	#	1.2	0	0	0	60	24	.22	37	4200	N	4	46	2	2	0	0	0	1	#	6	22	1	0
OCT	69	37	54	91	11	.4	2.3	#	.7	#	2	2	66	30	.18	32	4250	N	4	46	3	2	0	#	#	1	1	#	10	8	0
NOV	55	28	42	80	5	.4	1.6	#	.5	1	10	5	76	42	.15	27	4400	S	4	62	5	4	0	1	#	#	2	0	#	21	0
DEC	45	21	33	69	-14	.4	1.5	#	1.0	2	5	5	81	52	.12	23	4500	S	4	50	5	4	0	1	#	0	4	0	0	28	1
ANN	67	38	53	105	-14	5.1	2.4	#	1.8	11	70	18	67	33	.17	31	4400	S	5	62	4	38	0	8	0	12	15	60	140	140	2
EYR	19	19	19	19	19	19	19	19	19	19	19	19	25	25	25	25	26	25	25	19	24	19	19	19	19	21	21	19	19	19	19

REMARKS: *DATA NOT AVAILABLE. #LESS THAN 0.5 DAY, 0.5 OR 0.05 INCH, OR 0.5 PERCENT AS APPLICABLE.
THE VALUE LISTED UNDER "PRESS ALT FEET 99.95%" INDICATES IT IS EXCEEDED ONLY 0.05% OF THE TIME.
EYR MEANS EQUIVALENT YEARS OF RECORD (I.E. THE ACTUAL NUMBER OF YEARS UTILIZED IN THE COMPUTATIONS FROM THE OVERALL PERIOD OF RECORD, POR).

FLYING WEA &	HRS LST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CEILING	00-02	10	8	7	5	4	3	0	0	1	2	7	12	5	21
LESS 5000	03-05	12	10	7	6	5	3	0	0	1	2	8	14	6	24
FT AND/OR	06-08	15	11	9	7	6	3	0	0	1	3	9	17	7	25
VISIBILITY	09-11	14	10	11	10	9	6	0	0	1	4	9	13	7	25
LESS 5 MI	12-14	13	12	16	11	11	5	0	0	2	5	10	14	8	25
	15-17	12	12	13	11	10	5	2	1	2	4	8	12	8	25
	18-20	10	10	9	7	9	5	1	2	2	3	5	11	6	25
	21-23	10	8	6	6	6	4	1	1	1	2	5	10	5	23
	ALL HRS	12	10	10	8	8	4	1	1	1	3	8	13	7	25
CEILING	00-02	4	3	1	0	0	0	0	0	0	0	2	6	1	21
LESS 1000	03-05	6	4	1	1	0	0	0	0	0	0	2	7	2	24
FT AND/OR	06-08	7	4	2	1	0	0	0	0	0	0	3	8	2	25
VISIBILITY	09-11	5	3	1	1	0	0	0	0	0	0	2	5	1	25
LESS 3 MI	12-14	3	2	2	1	1	0	0	0	0	0	2	3	1	25
	15-17	2	2	1	1	0	0	0	0	0	0	1	3	1	25
	18-20	3	2	1	0	0	0	0	0	0	0	1	4	1	25
	21-23	4	2	1	0	0	0	0	0	0	0	1	5	1	23
	ALL HRS	4	3	1	1	0	0	0	0	0	0	2	5	1	25
CEILING	00-02	4	2	1	0	0	0	0	0	0	0	2	6	1	21
LESS 600	03-05	5	3	1	0	0	0	0	0	0	0	2	7	2	24
FT AND/OR	06-08	6	4	2	1	0	0	0	0	0	0	3	7	2	25
VISIBILITY	09-11	4	3	1	1	0	0	0	0	0	0	2	4	1	25
LESS 2 MI	12-14	2	2	1	0	0	0	0	0	0	0	1	2	1	25
	15-17	2	2	1	0	0	0	0	0	0	0	1	2	1	25
	18-20	2	2	1	0	0	0	0	0	0	0	1	3	1	25
	21-23	3	1	0	0	0	0	0	0	0	0	1	4	1	23
	ALL HRS	3	2	1	0	0	0	0	0	0	0	1	4	1	25
CEILING	00-02	3	1	1	0	0	0	0	0	0	0	1	5	1	21
LESS 500	03-05	4	2	1	0	0	0	0	0	0	0	2	6	1	24
FT AND/OR	06-08	5	3	1	1	0	0	0	0	0	0	2	6	2	25
VISIBILITY	09-11	3	2	1	0	0	0	0	0	0	0	1	3	1	25
LESS 1 MI	12-14	1	1	1	0	0	0	0	0	0	0	1	1	0	25
	15-17	1	1	1	0	0	0	0	0	0	0	0	1	0	25
	18-20	1	1	0	0	0	0	0	0	0	0	1	2	0	25
	21-23	2	1	0	0	0	0	0	0	0	0	1	4	1	23
	ALL HRS	2	2	1	0	0	0	0	0	0	0	1	4	1	25

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3 Civil Engineering Laboratory, Port Hueneme
  Commanding Officer (1)
  Technical Library (1)
  L03AE, Dave Holmes (1)
3 Naval Academy, Annapolis

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Library (1)
Mechanical Engineering Department, Professor Chin Wu (1)
2 Naval Postgraduate School, Monterey
1 Naval Research Laboratory
1 Office of Naval Research Branch Office, Boston
1 Office of Naval Research Branch Office, Chicago
1 Office of Naval Research Branch Office, New York
1 Office of Naval Research Branch Office, Pasadena
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1 Air Force Academy (Library)
1 Air University Library, Maxwell Air Force Base
1 Assistant Secretary of Defense (Energy, Environment and Safety)
12 Defense Technical Information Center
1 Assistant Commissioner for Minerals, Anchorage, AK
1 Bureau of Mines, El Centro, CA (Don H. Baker, Jr.)
1 Bureau of Reclamation, Boulder City, NV
1 California Assembly Office of Research, Sacramento, CA (Andy Gunther)
1 California Department of Conservation, Sacramento, CA
1 California Department of Water Resources, Sacramento, CA
1 California Division of Mines and Geology, Sacramento, CA
1 California Energy Co., Inc., Santa Rosa (James Moore)
1 California Energy Resources Conservation and Development Commission, Sacramento, CA (Syd Willard)
1 California State Land Division, Sacramento, CA
1 Department of Energy
1 Department of Energy, Division of Geothermal Energy, Idaho Operations, Idaho Falls, ID
1 Department of Energy, Division of Geothermal Energy, Nevada Operations, Las Vegas, NV
1 Idaho Bureau of Mines and Geology, Moscow, ID
1 National Academy of Engineering, Alexandria, VA (W. F. Searle, Jr.)
1 National Academy of Sciences (Dr. Robert S. Shane, National Materials Advisory Board)
1 Nevada Bureau of Mines, Reno, NV
2 Applied Physics Laboratory, Johns Hopkins University, Laurel, MD
4 United States Geological Survey, Menlo Park
Dr. Bacon (1)
Dr. Christianson (1)
Dr. Duffield (1)
Reid Stone (1)
1 Associated Universities, Inc., Upton, NY (Brookhaven National Laboratory)
1 Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA
1 Case Western Reserve University, Cleveland, OH (Department of Metallurgy and Materials Science)
1 Colorado Energy Research Institute, Golden, CO
1 EG&G Idaho, Inc., Idaho Falls, ID
1 Electric Power Research Institute, Menlo Park, CA
1 Franklin Institute, Philadelphia, PA (Library, Miriam Padusis)
1 Geothermal Energy Institute, New York, NY
1 Geothermal Resources Council, Davis, CA (Dave Anderson)
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1 Oak Ridge National Laboratory, Oak Ridge, TN
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1 University of Hawaii, Honolulu, HI
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2 University of Southern California Law Center, Los Angeles, CA
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1 University of Utah, Research Institute Earth Sciences Group, Salt Lake City, UT